CFD ANALYSIS OF HEAT TRANSFER IN A HELICAL COIL HEAT EXCHANGER USING FLUENT

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NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

CFD ANALYSIS OF HEAT TRANSFER IN A HELICAL COIL HEAT EXCHANGER USING FLUENT

A thesis submitted in partial fulfillment of the requirements for the degree of

Bachelor of technology
In
Mechanical engineering
By

SHASHI SHEKHAR

Under the guidance of
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National Institute of Technology

Rourkela 769008

CERTIFICATE

National Institute of Technology

Rourkela

This is to certify that the work in this thesis entitled, "**CFD ANALYSIS OF HEAT TRANSFER IN A HELICAL COIL HEAT EXCHANGER USING FLUENT**" submitted by **Shashi Shekhar** in partial fulfillment of the requirements for the degree of Bachelor of Technology in Mechanical Engineering, during session 2012-2013 is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the project has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Dr. Ashok Kumar Satapathy
(Supervisor)
Associate Professor
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Shashi shekhar

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CONTENT:

ABSTRACT

This thesis focuses on the CFD analysis of flow of fluid through a helical coil heat exchanger. Also on the enhancement in convective heat transfer in between the fluid and the surrounding surface in these helical coils which has been a major topic of study as reported by many researchers. As helical coil have compact size and higher heat transfer coefficient they are widely used in industrial applications such as power generation, nuclear industry, process plant, refrigeration, food industry, etc.

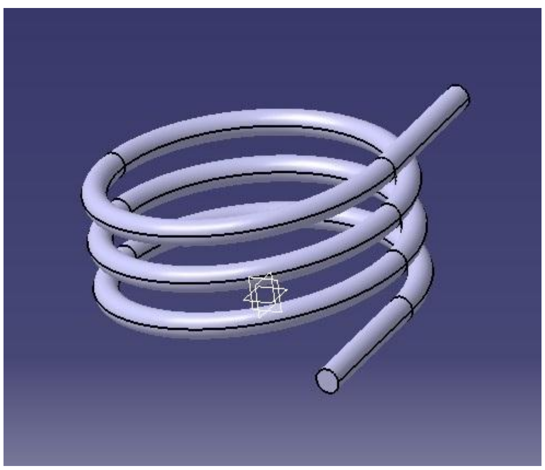
In this study, an attempt has been made to study the parallel flow and counter flow of inner hot fluid flow and outer cold fluid flow, which are separated by copper surface in a helical coil heat exchanger. The temperature contours, velocity vectors, total pressure contours, total heat dissipation rate from the wall of the tube were calculated and plotted using ANSYS 13.0. Copper was used as the base metal for the inner and outer pipe and the fluid was taken as hot water for inner flow and cold water for outer flow.

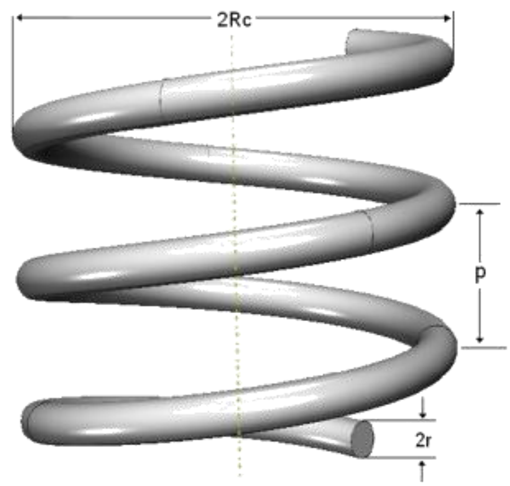
CHAPTER 1

INTRODUCTION ABOUT THE PROJECT

Heat transfer in helical coils are higher than as compared to straight coils. Because of its compact size, higher film coefficient, they are widely used in industrial applications like power generation, nuclear industry, process plant, heat recovery system, chemical process industries etc. These heat exchanger are used to control the temperature of the reactors for exothermic reactions. They have less expensive design. Helical geometry allows the effective handling at higher temperatures and extreme temperature differentials without any highly induced stress or expansion of joints. Helical coil heat exchanger consists of series of stacked helical coiled tubes and the tube ends are connected by manifolds, which also acts as fluid entry and exit locations.

Schematic diagram of helical coil heat exchanger





Natural convection is a process or type of heat transfer, in which the fluid motion is caused by density differences in the fluid occurring due to temperature gradients. Here the fluid which surrounds a heat source receives heat, becomes less dense and rises. The fluid that is surrounding the hot fluid is cooler and then moves in to replace it. Then further that cooler fluid gets heated and the process continues, forming convection current. The driving force for this process is buoyancy, a result of difference in the fluid density. Natural convection has attracted a great deal of attention from researchers because of its presence both in nature and engineering applications.

Forced convection in a heat exchanger is the transfer of heat from one moving stream to another stream through the wall of the pipe. The cooler fluid removes heat from the hotter fluid as it flows along or across it. If it moves along the hot stream then it's called parallel flow and if they are across then its counter flow.

Heat transfer coefficient:

As we studied, if the heat transfer is occurring in a stream due to density difference then its convective heat transfer. If a film is placed in between fluid of different density then conduction heat transfer will occur through that film. The equation of rate of heat transfer under steady state is given by:

$Q=hA\ (t_w-t_{atm})$,

Where h= coefficient of heat transfer (W/m^2K)

A= area of the wall

T_w=wall temperature

T_{atm}=surrounding temperature.

The value of 'h,Heat Transfer Coefficient' depends upon the properties of fluid.. It depends on the different properties of fluid, dimensions of the film surface and velocity of the fluid flow as well as nature of flow.

CHAPTER 2

LITERATURE SURVEY

J.S. Jayakumar [1]. According to his study it was attempted to run experimental and theoretical analysis of a helical coiled heat exchanger, in which heat transfer is between fluid-fluid. There exists no previous analysis for helical coil heat exchanger though there are many researches for double pipe heat exchanger. Experimental setup was fabricated to get the output in estimation of heat transfer characteristics, then this experimental data was compared with the CFD calculation using CFD package FLUENT 6.2.

Experimental setup and procedure:-

The pipe for the construction of helical coil has 10 mm inner diameter and 12.7 mm outer diameter. Pitch of the coil is 300 mm and tube pitch is 30 mm. Material used was stainless steel SS304.

The setup consist of a shell which encloses the helical coil. Cold fluid enters from bottom to top leaving the shell through the nozzle at top. The coil assembly can be replaced if needed.

A tank was provided with electrical heaters to heat the water that to be circulated in helical coil. It consist of three heaters having total power of 5000W. To control the temperature of water at the inlet a controller was connected. A centrifugal pump with ½ HP power rating is connected to pump the hot water in helical coil. RTD (resistance thermometer detectors) are added to measure the inlet and outlet temperatures of the hot fluid and the values are available at the display screen. Cooling water from a constant temperature tank is provided through the shell side and its inlet and outlet temperatures are measured. Its flow is adjusted such that the rise in temperature is not exceeding 5^oC.

After the temperature attain a constant steady value, by conducting 5 different flow rates through the coil and for three different values of inlet temperature of the helical coil, measurements are taken of the values of flow rates of the hot and cold fluids, temperature at inlet and exit is noted and the power input to the heater and the pump are noted.

These heat transfer characteristics helical coil setup is further studied using CFD code FLUENT. The CFD results matched accordingly with the experimental results within the error limit. A relation was developed to calculate the inner heat transfer coefficient of the helical coil. Based on the results generated under different conditions it may be used to obtain a generalized correlation that may be applicable to other various coil configuration.

A.B. Korane [2] has performed comparative analysis to study friction factor characteristics of shell and helically coiled tube heat exchanger. He continued his studies on two geometries helical coil heat exchanger and square coil pattern having round cross section. Both the coil were constructed by using a 3.33 meter straight copper tube having 10 mm inner diameter and 12 mm outer diameter in 6 turns with pitch 0 mm. the heat exchanger was made by copper tubing and brass connection. Both laminar and turbulent flow were analyzed for the Reynolds number range of 886-6200 and having different mass flow rates. The hot water tank with the 3KW capacity thermostatic electric heater was used to pump the hot water through the tubing. The mass flow rates varies from 0.003-0.024 kg/s for the hot water which comes from hot water tank. Cold water with the flow rate of 0.003-0.024kg/s is supplied. And the flow rates are controlled by the ball valves provided.

The two helical coils tube side friction factor was determined individually for laminar and turbulent flow. The performance was then discussed according to friction factor and pressure drop.

According to this study he came to the conclusion that

- Performance for the square coil is more than circular helical coil.
- Empirical correlations were developed for both square and circular coils on both laminar and turbulent flow.
- Both the heat exchangers were analyzed for laminar and turbulent flow configuration.

The friction factor is minimum for the square coil as compared to circular coil.

Daniel Flórez-Orrego [3] have studied the characteristics of single phase cone shaped helical coil heat exchanger. They conducted experiments on a prototype of cone helical coil heat exchanger with maximum diameter of 15 cm and minimum diameter as 7.5 cm, 3/8 inch pitch and axial length of 40 cm. the flow was in both laminar and turbulent and the range of Reynolds number and prandtl number are 4300-18600 and 2-6 respectively. According to this study nusselt number can be found out by $Nu=CRe^{m}Pr^{n}$, where C,m are constants that to be determined and nis the prandtl number index which is taken as 0.4. An empirical correlation was proposed for average nusselt number, and it was found that there is a maximum deviation of 23%. Inclination of the velocity vector components in the secondary flow was observed unlike in the straight helical coils. These correlations are not reliable and it failed to give any deviation in nusselt number due to the tapering and the effect of pitch.

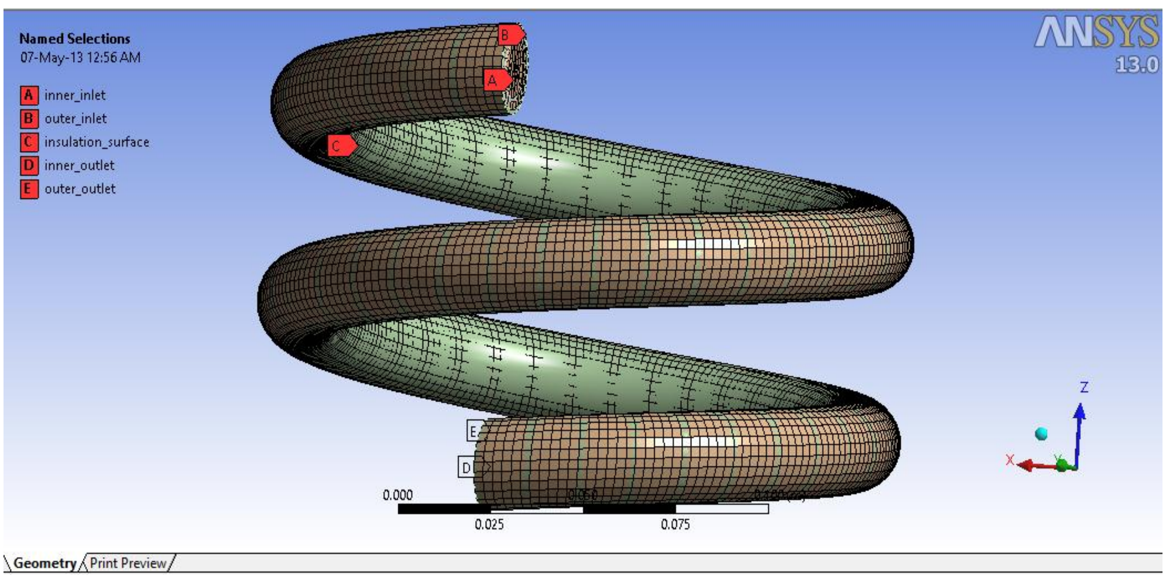
CHAPTER 3

CFD ANALYSIS

3.1. BOUNDARY CONDITIONS:

We are taking the inlet and outlet conditions as velocity inlet and pressure outlet. As this is counter flow of inner hot fluid flow and outer cold fluid flow so there will be two inlet and outlet respectively. There is a pipe which separates the two flows which is made by copper. The detail about all boundary conditions are as follows. Inner fluid is taken as hot water and outer fluid is taken as cold water.

	Boundary condition type	Velocity magnitude	Turbulent kinetic Energy	Turbulent dissipation rate	temperature
Inner inlet	Velocity Inlet	1.6 m/s	0.01	0.1	333 K
Inner outlet	Pressure Outlet	-	-	-	-
Outer inlet	Velocity Inlet	1.5m/s	0.01	0.1	283 K
Outer outlet	Pressure Outlet	-	-	-	-



3.2. DIMENSIONS:

Diameter of inner inlet= 0.6 inch

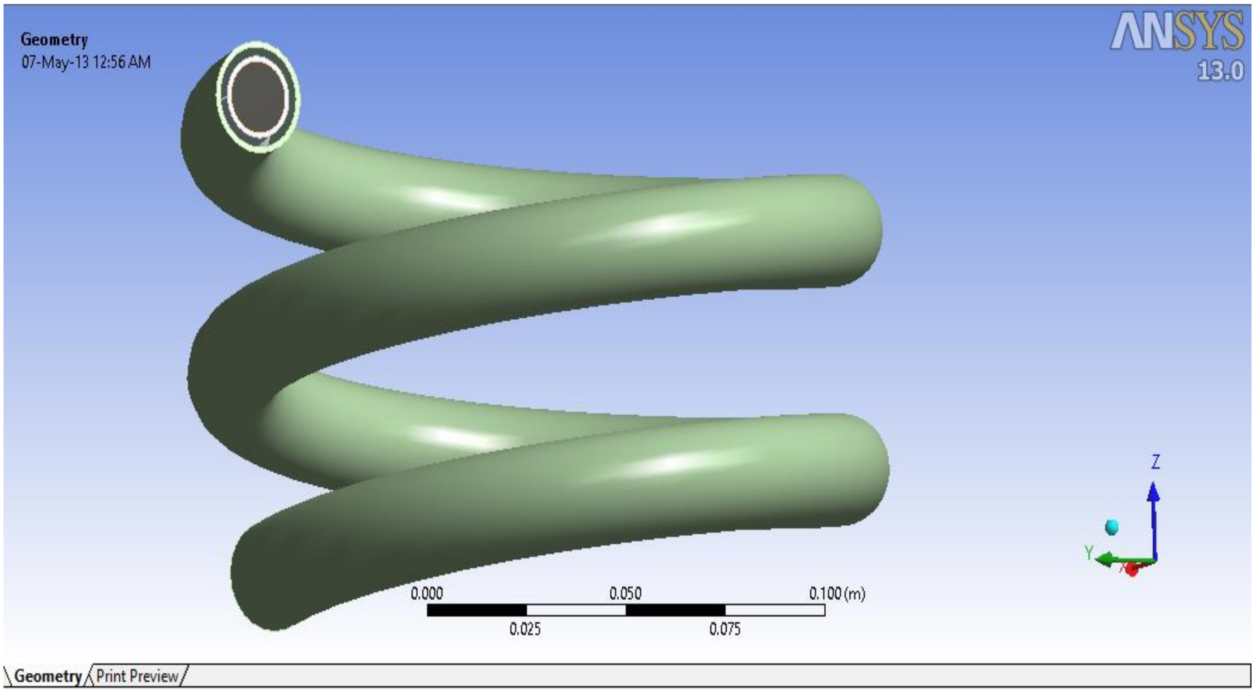
Diameter of inner pipe= 0.68 inch

Diameter of outer inlet= 0.84 inch

Diameter of outer pipe= 0.93 inch

Diameter of coil= 6 inch

Density is taken in y direction = 9.81 m/s^2

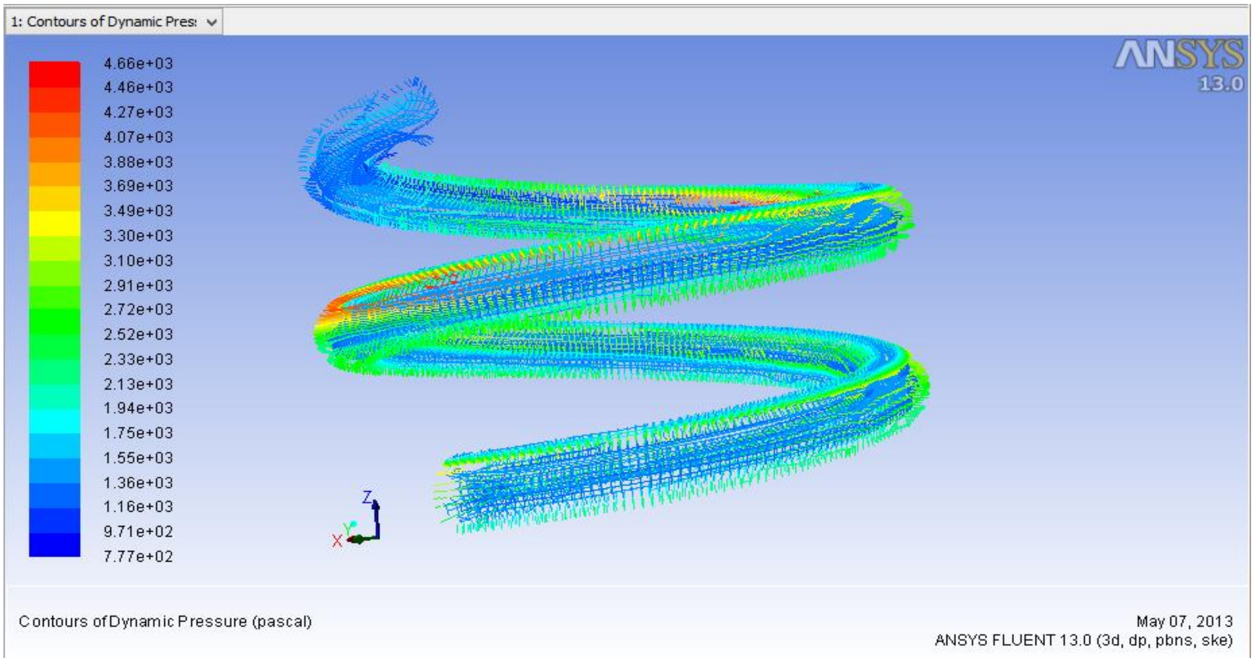


CHAPTER 4

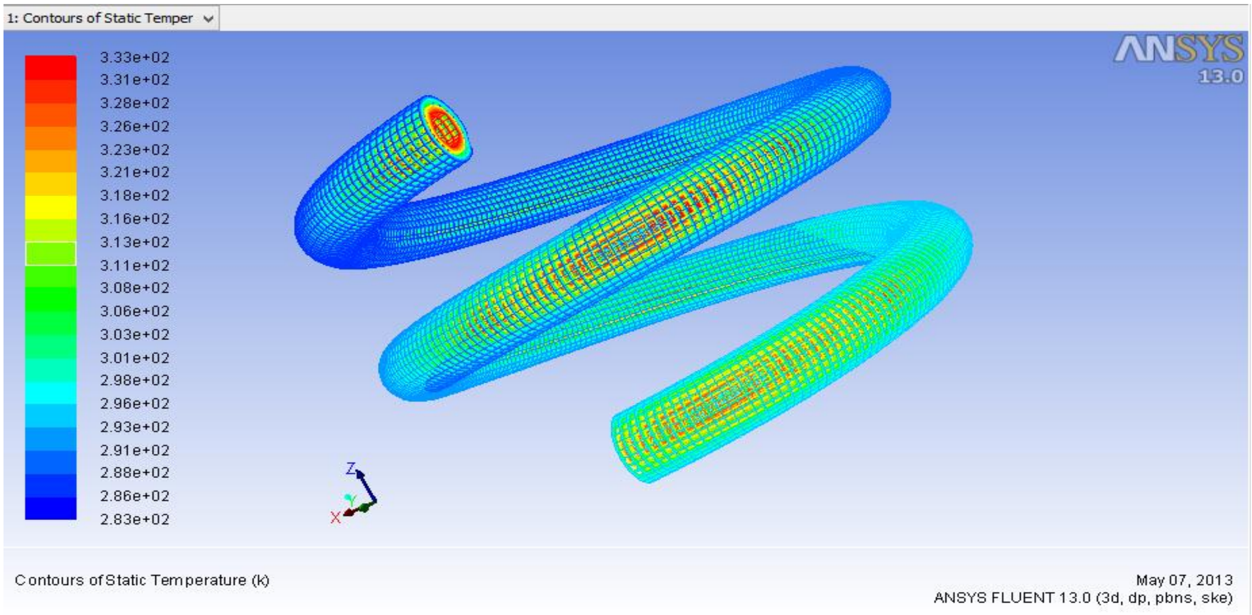
RESULTS AND DISCUSSION

4.1. CONTOURS:

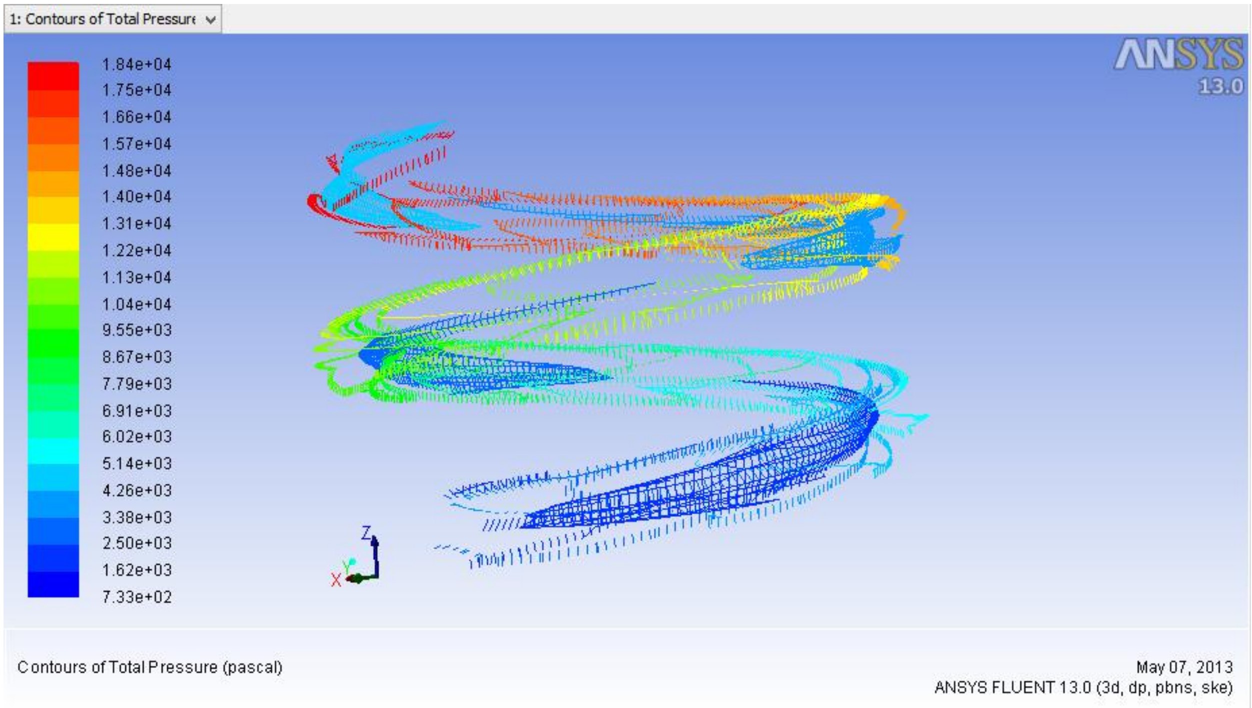
The temperature, pressure and velocity distribution along the heat exchanger can be seen through the respective contours.



Contours of Dynamic Pressure in Pascal

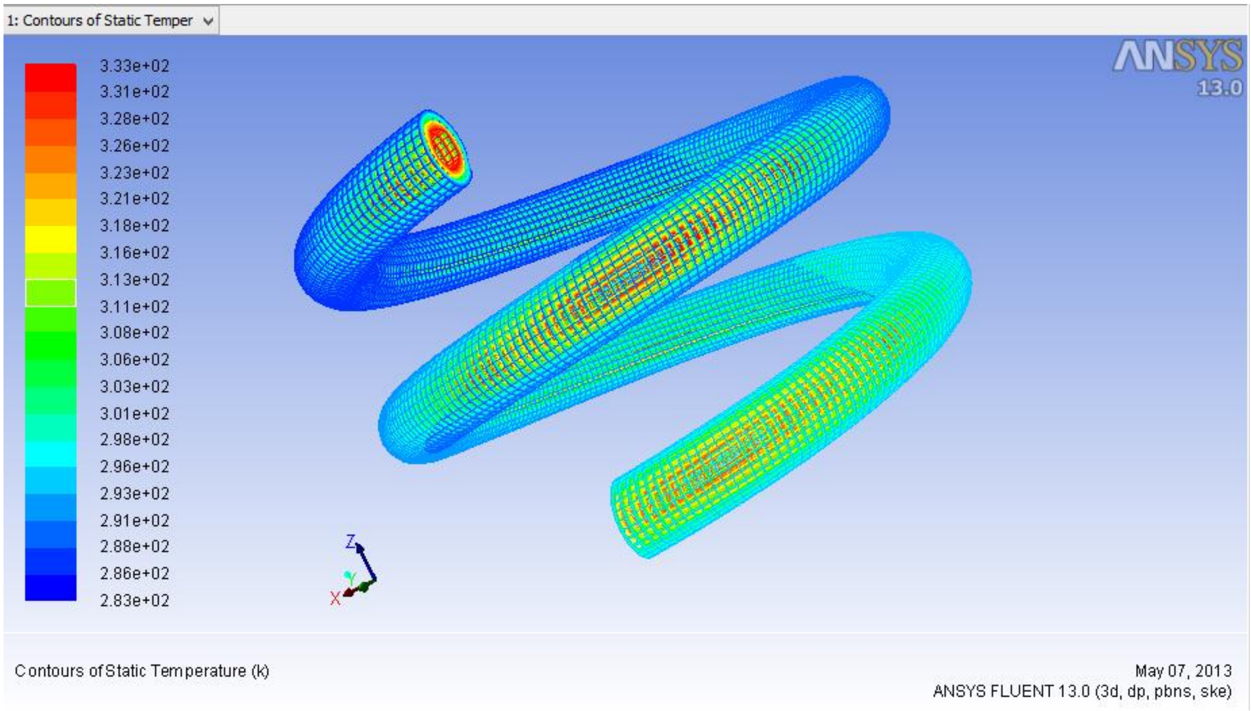


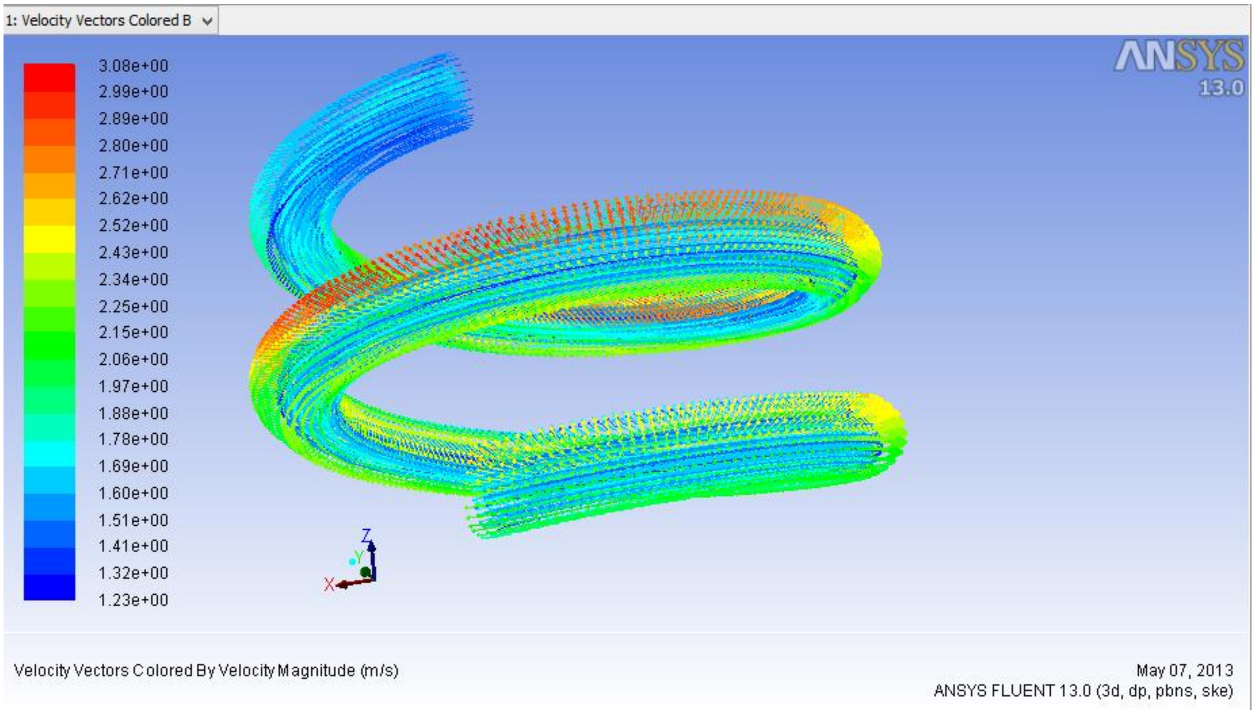
Contours of static temperature



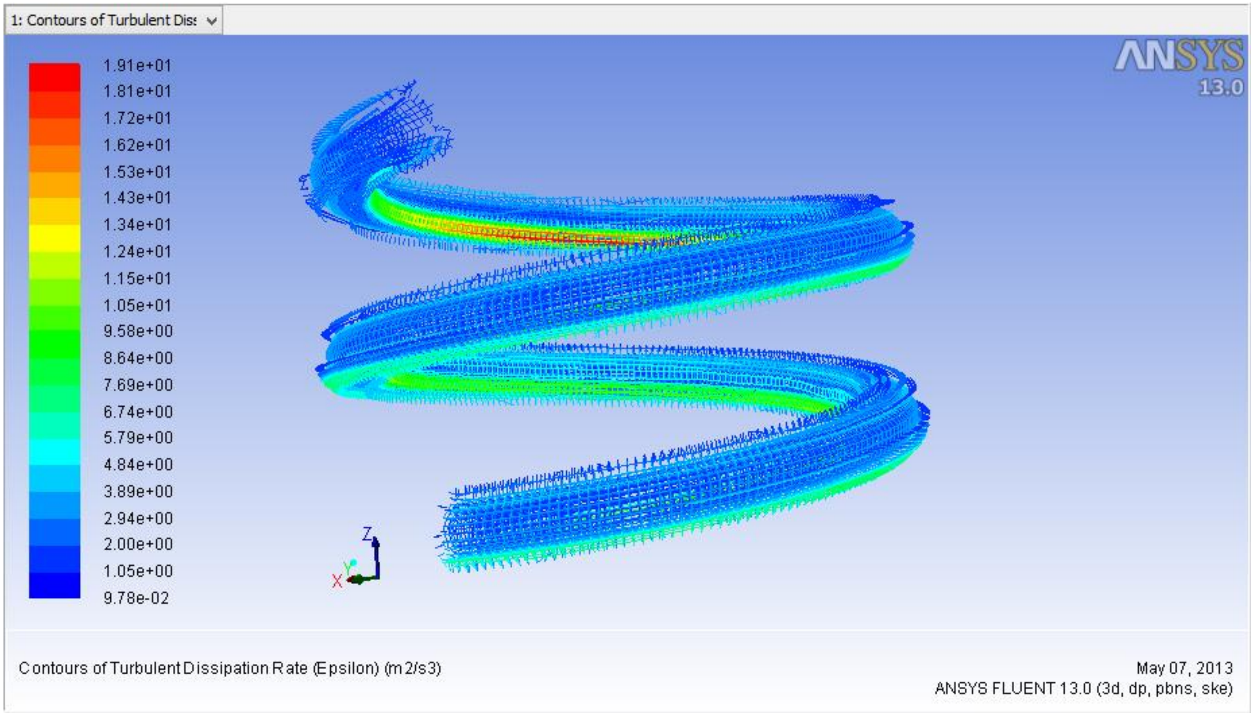
Contours of total pressure

Contours of static temperature

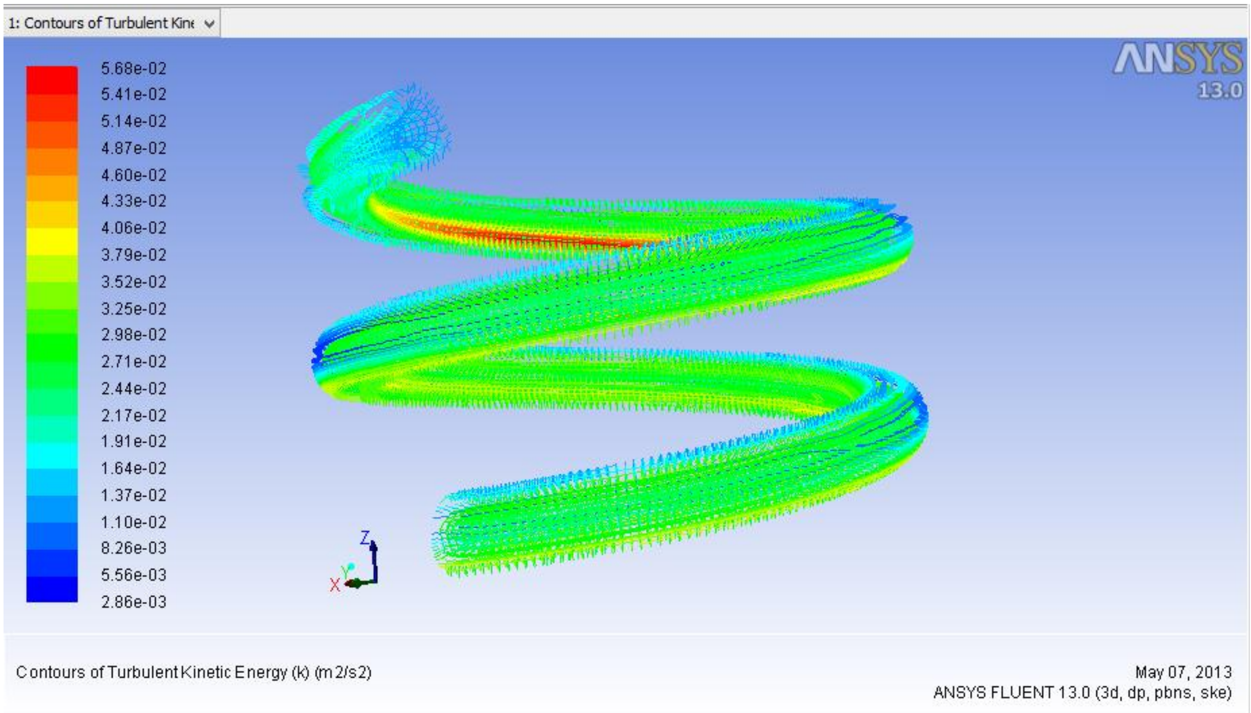




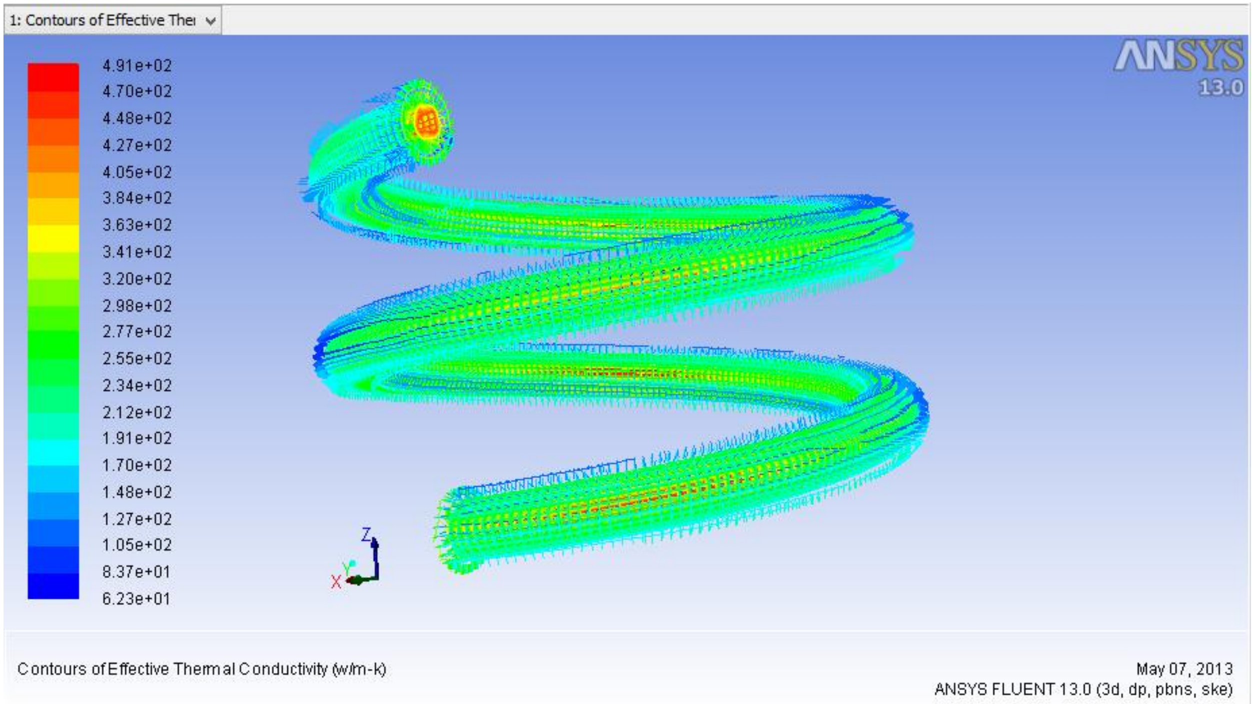
Contours of velocity vectors



Contours of turbulent dissipation rate

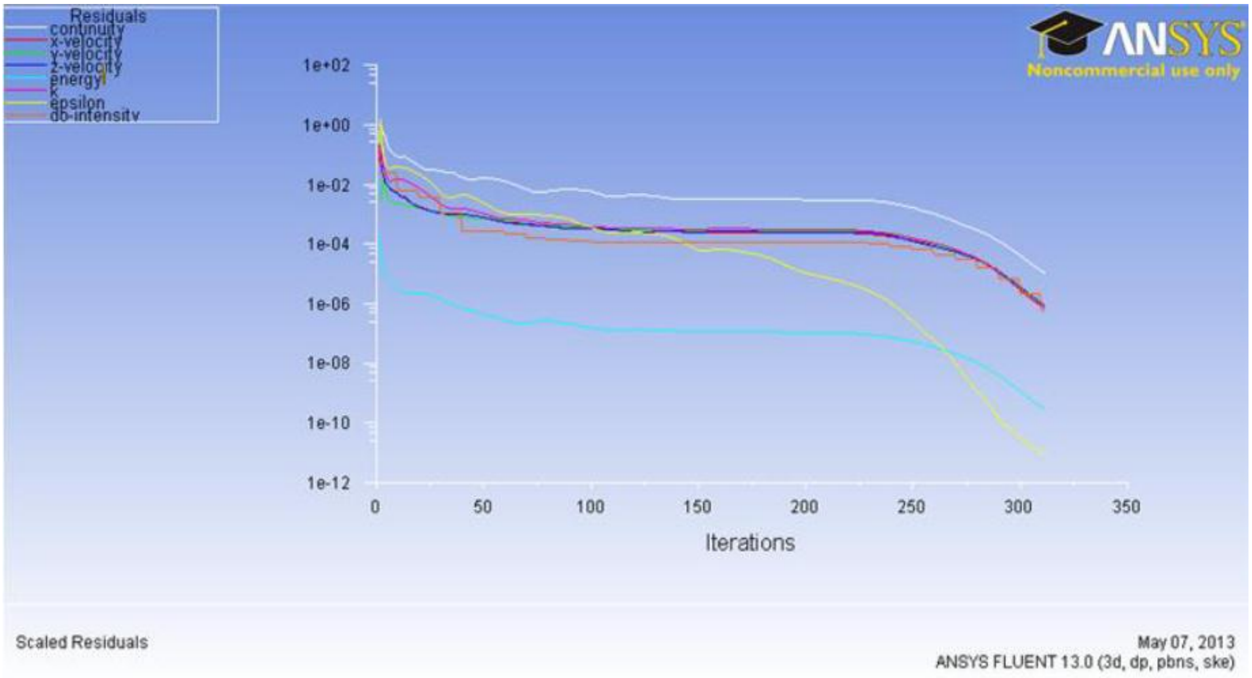


Contours of turbulent kinetic energy

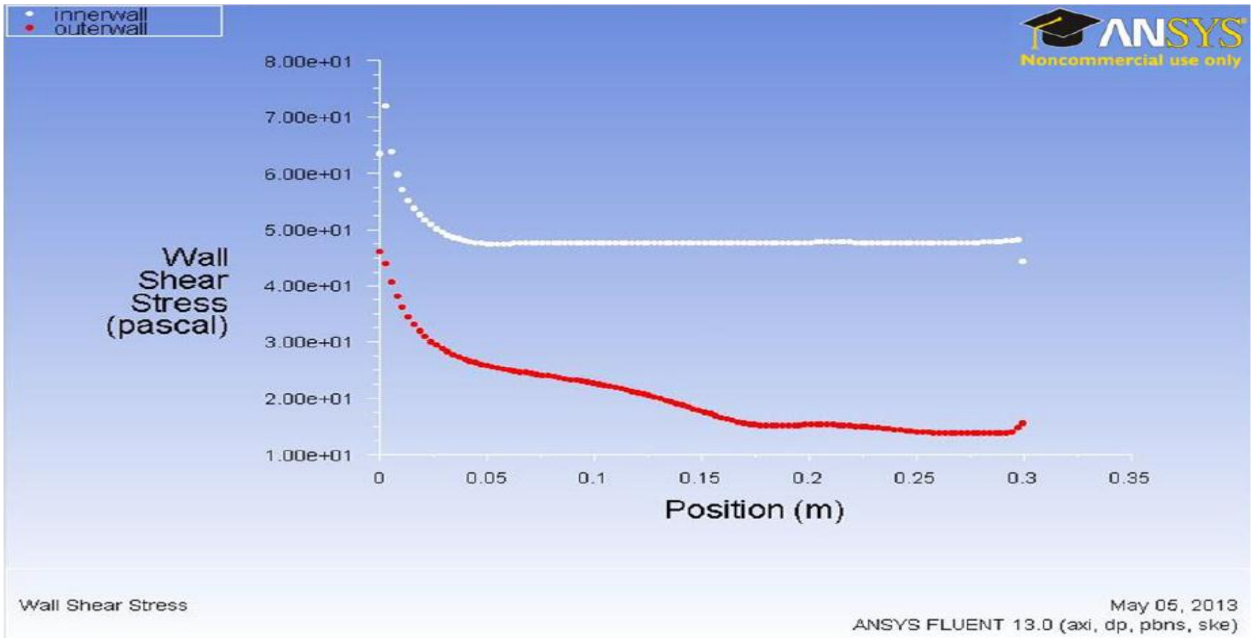


Contours of effective thermal conductivity

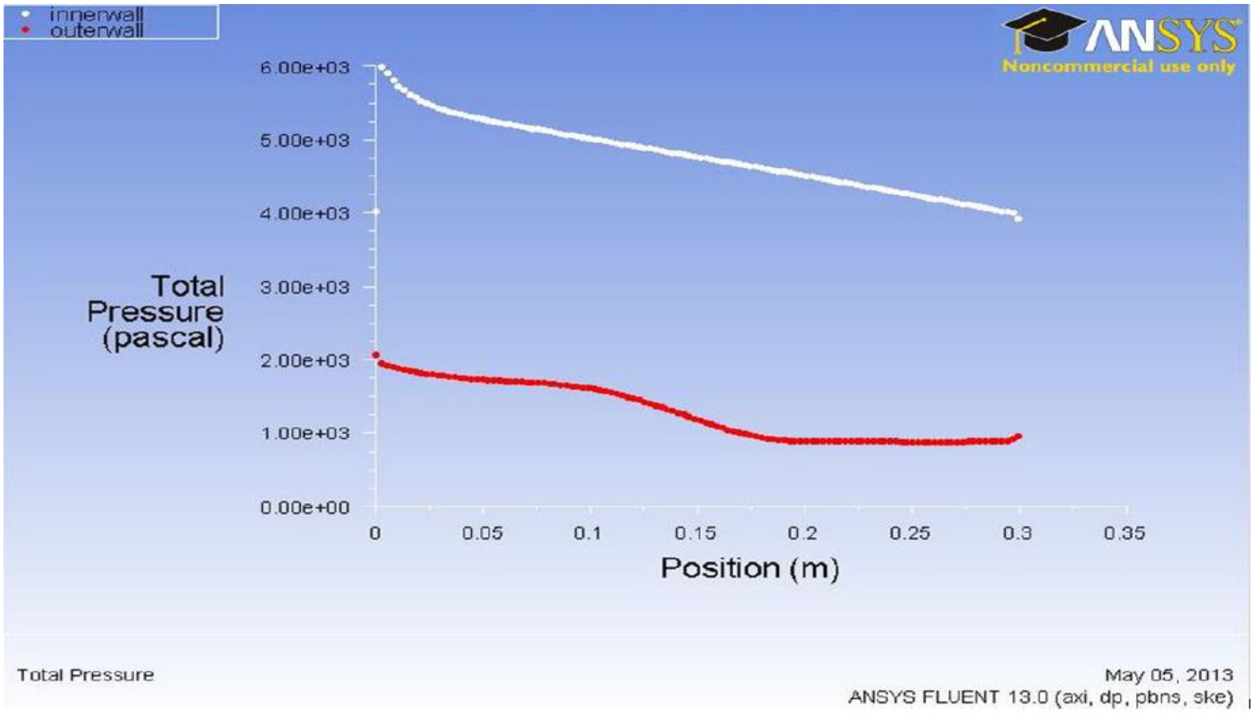
4.2. PLOTS:



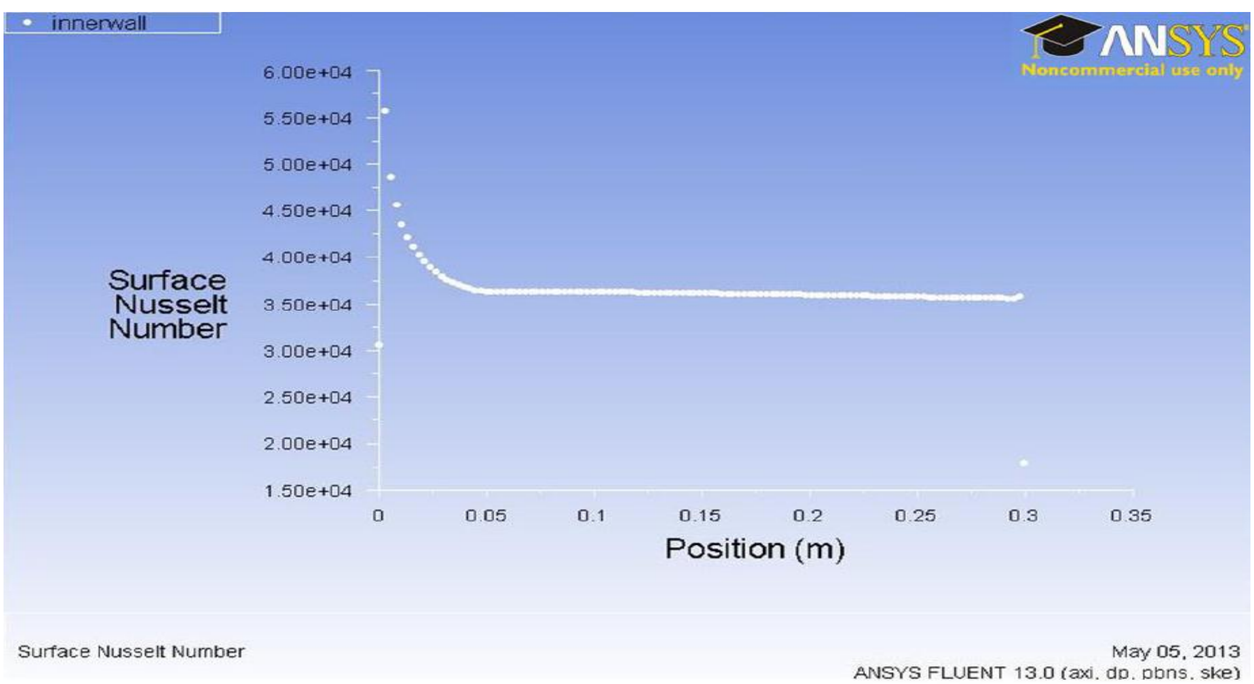
Scaled residuals



Wall Shear Stress Plot for Inner-wall And Outer-wall



Total Pressure Plot for Innerwall and Outerwall



Surface Nusselt Number Plot for Inner-wall

CONCLUSION:

ANSYS 13.0 is used for the numerical study of characteristics of heat transfer in a helical coiled double pipe heat exchanger for parallel flow and these results were compared with the experimental results from different study papers and were found well within proper error limit. The study relates the heat transfer performance of the parallel flow configuration and the counter flow configuration. Nusselt number was determined for different points along the pipe length. It was found to be varying from 340-360.

We concluded different heat transfer properties at different points along the pipe length in this study like temperature, static pressure, total pressure, kinetic energy etc., for the constant temperature and constant wall heat flux conditions. The velocity vector plot concludes that the fluid particles are undergoing an oscillatory motion inside both the pipes. And pressure and temperature contours shows that velocity and pressure values were higher for outer sides than inner sides of the pipes.

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NOMENCLATURE

1. A = area of heat transfer (m^2)
2. De= Dean Number
3. H = heat transfer coefficient ($Wm^{-2}\ K^{-1}$)
4. H = tube pitch (m)
5. K = thermal conductivity ($Wm^{-1}\ K^{-1}$)
6. L= length of the pipe (m)
7. Nu= Nusselt number
8. Pr = Prandtl number
9. Q = heat transferred (W)
10. R= inner radius of the tube (m)
11. R = resistance the flow of thermal energy ($W^{-1}m^2\ K$)
12. Rc = pitch circle radius of the pipe (m)
13. Re= Reynolds number
14. U = velocity ($m\ s^{-1}$)
15. U = overall heat transfer coefficient (Wm−2 K−1)
16. V= volume (m3)
17. A = helix angle (rad)
18. δ = curvature ratio
19. Δ = (temperature) difference (K)
20. μ = viscosity ($kgm^{-1}\ s^{-1}$)
21. ρ = density (kgm^{-3})
22. av = average
23. i = internal
24. LM = log mean
25. o = external
26. ov = overall
27. w = wall